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Discussions
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# *Interactive comment on* "Shape dependence of snow crystal fall speed" *by* Sandra Vázquez-Martín et al.

**Sandra Vázquez-Martín et al.**

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Dear referee #2,

We sincerely appreciate your constructive feedback and time spent to read and evaluate this work. Please look at the lines at the end of this text that contain our responses to your comments.

Best regards,

Sandra et al.



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Discussion paper

Interactive comment on “Shape dependence of snow crystal fall speed” by Sandra Vázquez-Martín et al.

Anonymous Referee #2

Received and published: 8 December 2020

We sincerely appreciate the referee #2 for your constructive feedback and time spent to read and evaluate this work. Please see below our response to your comments.

*General comments: ——————————-

1) In the abstract, the points in the first "introduction" paragraph could be organized better and stated more succinctly, perhaps in about three sentences.

Thank you for pointing this out. We will modify the first “Introduction” paragraph in the Abstract in order to make it more concise and also better organized (see also the response to specific comment 1 of referee 1).

2) Lines 43 – 49: The recent work of Dunnavan (2020, JAS) should also be mentioned here as he shows how orientation and other factors account for much of the dispersion in ice fall speed for a given size.

Thanks for your suggestion. We will include that reference in the previous paragraph talking about the influence of the shape on the spread in fall speed, which in their study was more important than orientation.

3) Lines 50 – 52: Another reference that supports this is Mitchell et al. (2008, GRL), which shows how the cirrus ice fall speed affects cirrus cloud coverage and ice water path, and the resulting impact on radiation in the Community Atmosphere Model version 3 (CAM3).

Thank you for your suggestion. We will add Mitchell et al. 2008.

4) Figure 3 and elsewhere in paper where shape category 13 is mentioned: Shape

category 13 is ambiguous since it appears this can refer to any kind of ice particle and it also includes melting/sublimating ice particles of any shape apparently. Is this merely a "dust bin" category that includes all the other shapes that defy classification?

Our “dust bin” is the shape group (14). Group (13) is, as it says, melting and sublimating (mostly small) particles as shown in Fig. 1 attached as a pdf (see more details in Vázquez-Martín et al., 2020 “Shape Dependence of Falling Snow Crystals’ Microphysical Properties Using an Updated Shape Classification”). However, we think you are right in that shape group (14) should have better been divided into “Irregulars” (i.e. non aggregates) and “Aggregates”, that’s something we did not consider when first doing the shape classification.

5) Figure 3 and elsewhere in paper where shape category 14 is mentioned: Irregulars as defined in Lawson et al. articles are high density, blocky-type particles that are subdivided into small and large irregulars, but other authors may define them differently. How are they defined here? If irregulars here are similar to irregulars in Lawson et al. papers, then grouping them with aggregates may be a mistake, since unrimed aggregates are NOT high density; rather they are notoriously low density. Please show a photo of irregulars so readers will know what they look like.

Same as in 4), we think you are right in that shape group (14) should have better been divided into “Irregulars” (i.e. non aggregates) and “Aggregates”, that’s something we did not consider when first doing the shape classification. We have added pictures here (see Fig. 2 attached as a pdf) and referred readers in the MS to our previous work on shape classification, which contains many example images (Vázquez-Martín et al, 2020). In our dataset, we do not have many aggregates yet. However, in future, we will extend our dataset and then likely revise the shape grouping including a separate group for aggregates.

6) Lines 175 – 181: Regarding the large spread in fall speeds, the recent paper by Dunnavan (2020, J. Atmos. Sci.) shows snowflake (i.e., crystal aggregate) fall speeds

are most sensitive to particle shape differences (largely accounted for in this study) with secondary sensitivity to aggregate orientation. Please consider whether this Dunnavan study is relevant in explaining the large spread in fall speeds encountered here.

We will mention the spread in fall speed caused by shape variations (Dunnavan 2020) in the Introduction in response to your general comment 2). Responding to specific comment 15) of Referee 1, we will also extend the discussion on the reasons for the fall-speed spread in the next section on the binning method.

7) Figure 6: The legend contains a pink bar denoting the 68% confidence region, but a pink region is not evident in the plots. Perhaps it is sufficient to only show the 68% prediction bands?

This is indeed difficult to see. The confidence regions for Ma and Mb are shown as half-transparent pink and light blue, respectively. Here, they are almost entirely overlapping, making it difficult to make out where the pink region is. We will try to improve this, perhaps changing the v range to 0-1.0 m/s and removing the Mb prediction band will help. Otherwise, we will also consider your suggestion.

8) Section 3.3.1 on Orientation: A study by Kajikawa is the only one I know of containing observational results on natural ice crystal orientation during free-fall; please include this reference (Kajikawa, 1992, J. Meteorol. Soc. Japan), comparing orientation results from this study with the Kajikawa results.

Thank you, this is an interesting study. Kajikawa 1992 looked at falling motion with stable and unstable patterns, rather than at orientation directly as we did and found only small variations (few %) in the vertical speed with respect to the mean for individual trajectories. The smaller horizontal speeds showed more variations that Kajikawa linked to growth by aggregation.

9) Section 3.4 (Comparison with previous fall speed relationships): Ice fall speeds depend on temperature T and pressure P; what were the values assumed here? Was

this assumption applied universally to all of the studies in this intercomparison? If not, please ensure that all fall speeds in this intercomparison use the same T and P.

Thank you for raising this issue. We are aware of this fact and that different studies are based on measurements at different atmospheric conditions and may be adjusted to some normal conditions or not. Our measurement site is at an altitude of around 400 m, which corresponds to about a pressure difference of 50 hPa with respect to sea level. A pressure difference of 100 hPa (about 1000 m altitude difference) would result in about 5% difference in fall speed (see for example Khvorostyanov and Curry 2005, JAS 62, 4343-4357). A temperature difference of 10 K would cause a 2% speed difference. As these differences are relatively small compared to the typical speed differences between different studies we decided, for simplicity, to neglect these effects without any impact on the comparison. We will mention the altitude of our site and make a statement about the neglected P and T dependence of fall speed in the MS.

10) Figure 13, middle panel (stellar): Please mention that Curve 11 is based on the flow regime for larger ice particles, and should be closer to [VM] for the smaller D if the corresponding flow regime constants in [M] were used.

Thank you for pointing this out. We will mention that in the MS.

11) Lines 343-4: Sentence structure appears awkward; do you mean to say "Our shape group (5) contained only plates that were unrimed"?

The sentence will be modified accordingly and convey a little more detail.

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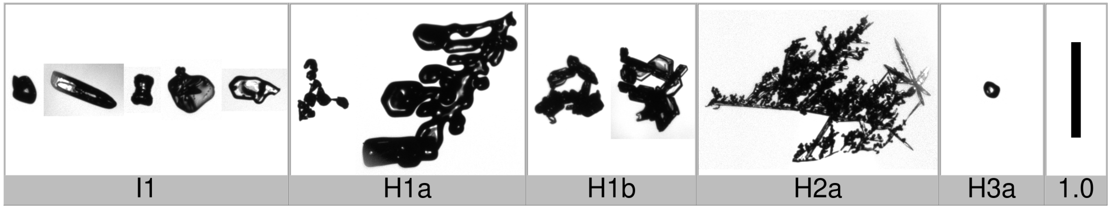


**Fig. 1.** General comment, #4)

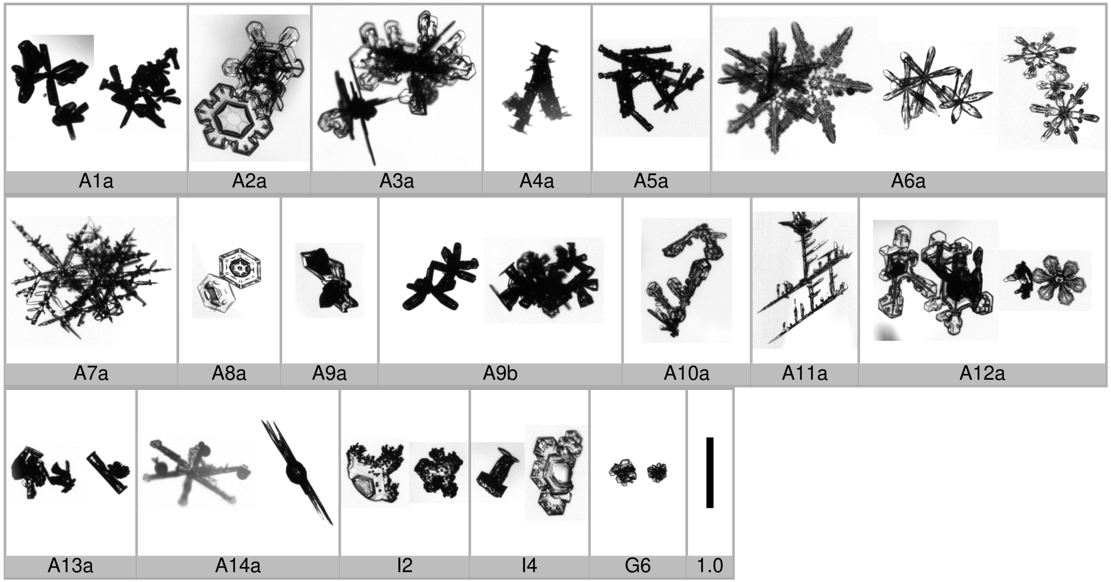


**Fig. 2.** General comment, #5)